The 9th Annual Monitoring and Situational Awareness Technical Conference – Session 2

New Normal in Energy Management Systems

NERC EMS Working Group
October 07, 2021

Today's Agenda

- Inverter-Based Resource Integration at Duke Energy
  - Adam Guinn, Duke
- Distributed Energy Resources
  - Daniel Moscovitz, PJM
- **10-minute Break**
- DER Order 2222
  - Kristin Swenson, MISO
- Modeling Distributed Energy Resources in CAISO systems
  - Ankit Mishra, CAISO
- Session Summary
  - Matt Lewis, NERC

Adam Guinn

Adam Guinn is a Lead Engineer in the Transmission and Operations Strategy group at Duke Energy. In his 17 years of professional work, he has developed several advanced marginal-dispatch-based dynamic schedules, integrated hundreds of Distributed Energy Resources within the EMS, created state estimation and power flow solutions, performed tuning and design work on EMS BA-level and AGC response systems, and developed data engineering and analytics solutions supporting business intelligence and equipment health analysis.

He graduated from North Carolina State University with two (2) Bachelor of Science degrees in Electrical and Computer Engineering, a Masters in Electric Power Systems Engineering, and a Renewable Electric Energy Systems Graduate Certificate; and is a licensed Professional Engineer in North Carolina.

Inverter-Based Resource Integration at Duke Energy

Duke Energy
Adam Guinn, PE
Lead Engineer

Introduction

- What is a Distributed Energy Resource (DER)?

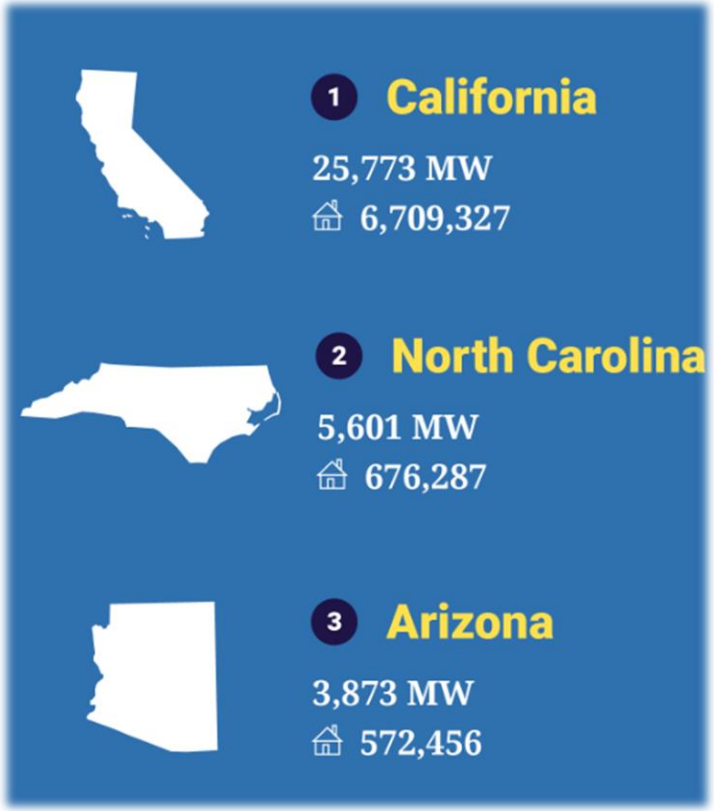
  Any resource on the distribution system that produces electricity and is not otherwise included in the formal NERC definition of the Bulk Electric System (BES)

  - NERC

- So…basically anything NERC hasn't defined in the BES definition
- Resources include, but are not limited to
  - Inverter-Based Resources (IBRs)
  - Diesel Generators
  - Hydro units
  - Biomass

https://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/Distributed_Energy_Resources_Report

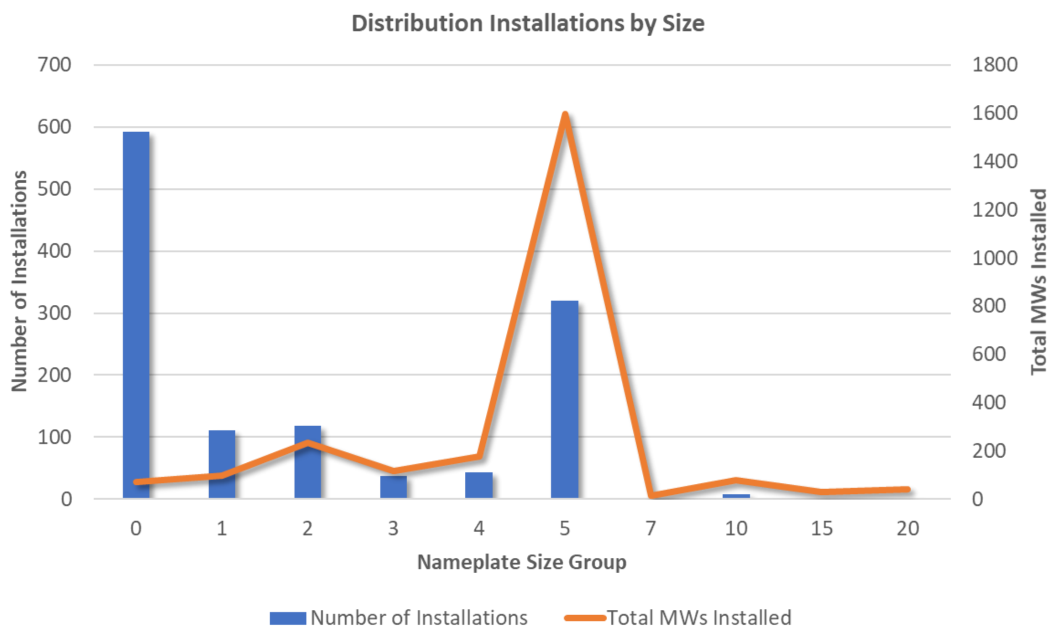
Why So Much Solar In North Carolina?

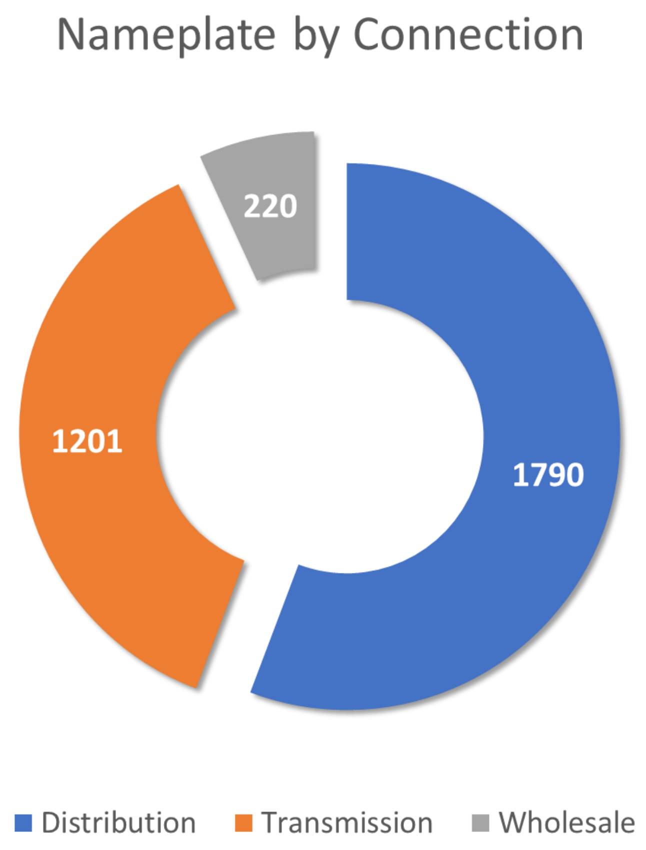


- NC is leader in PURPA-supported utility scale solar installed capacity
- NC is second, only to California, in total installed solar capacity
- Reasons
  - NC REPS – 12.5% of retail electricity sales from renewable energy resources by 2021
  - DEP long-term PPAs with avoided cost rates from $55 to $85 per MWh for Qualifying Facilities
  - 35% NC Renewable Energy Tax Credit (“RETC”) – ended 2015
  - 30% Federal solar investment tax credit incentive (“ITC”) – thru 2019 (extension??)

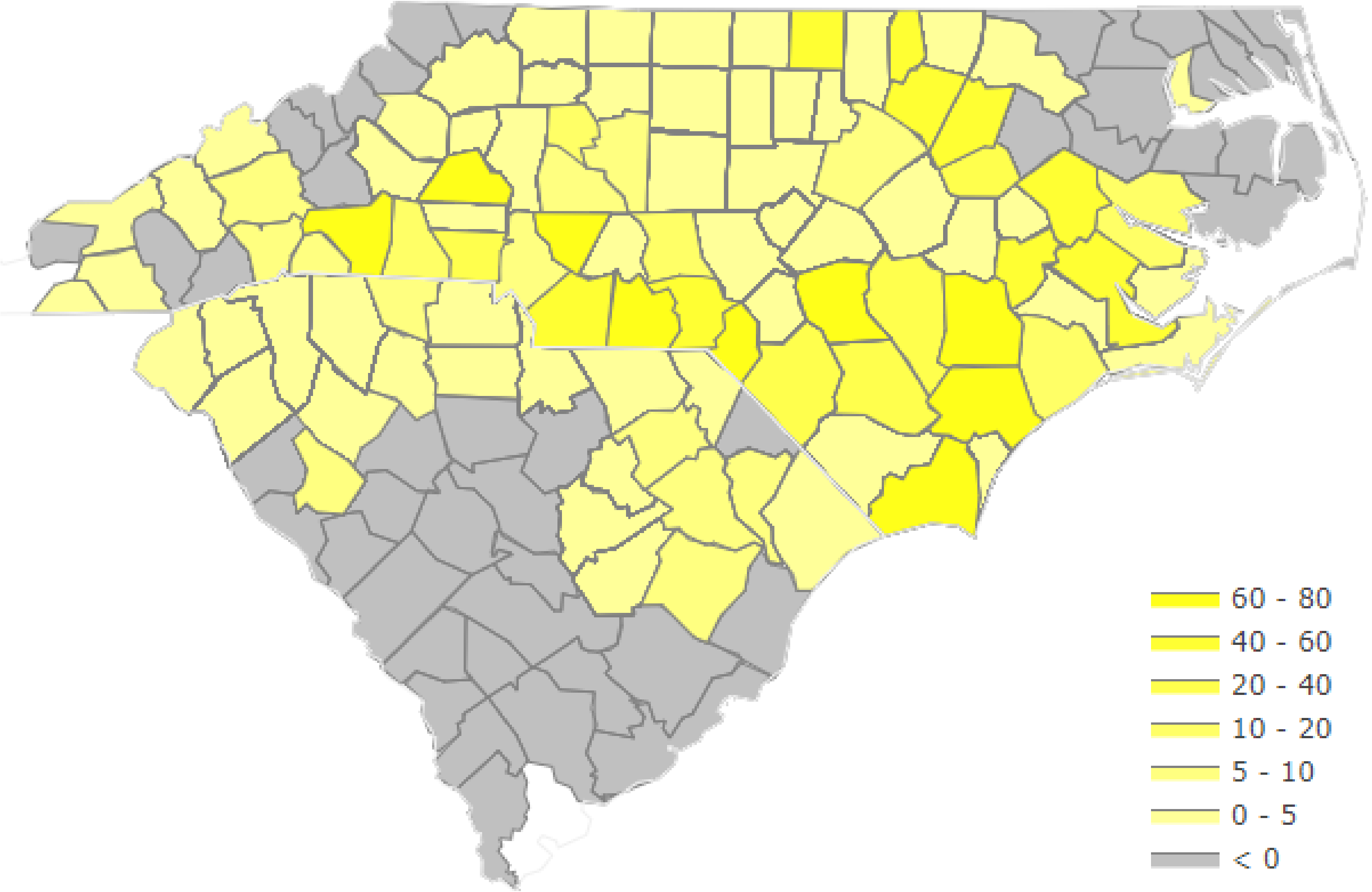
The Landscape

- DER penetration is primarily solar
  - Transmission-Connected: Sites ranging in size from 25 to 88 MW
  - Distribution-Connected: Sites range in size as follows:

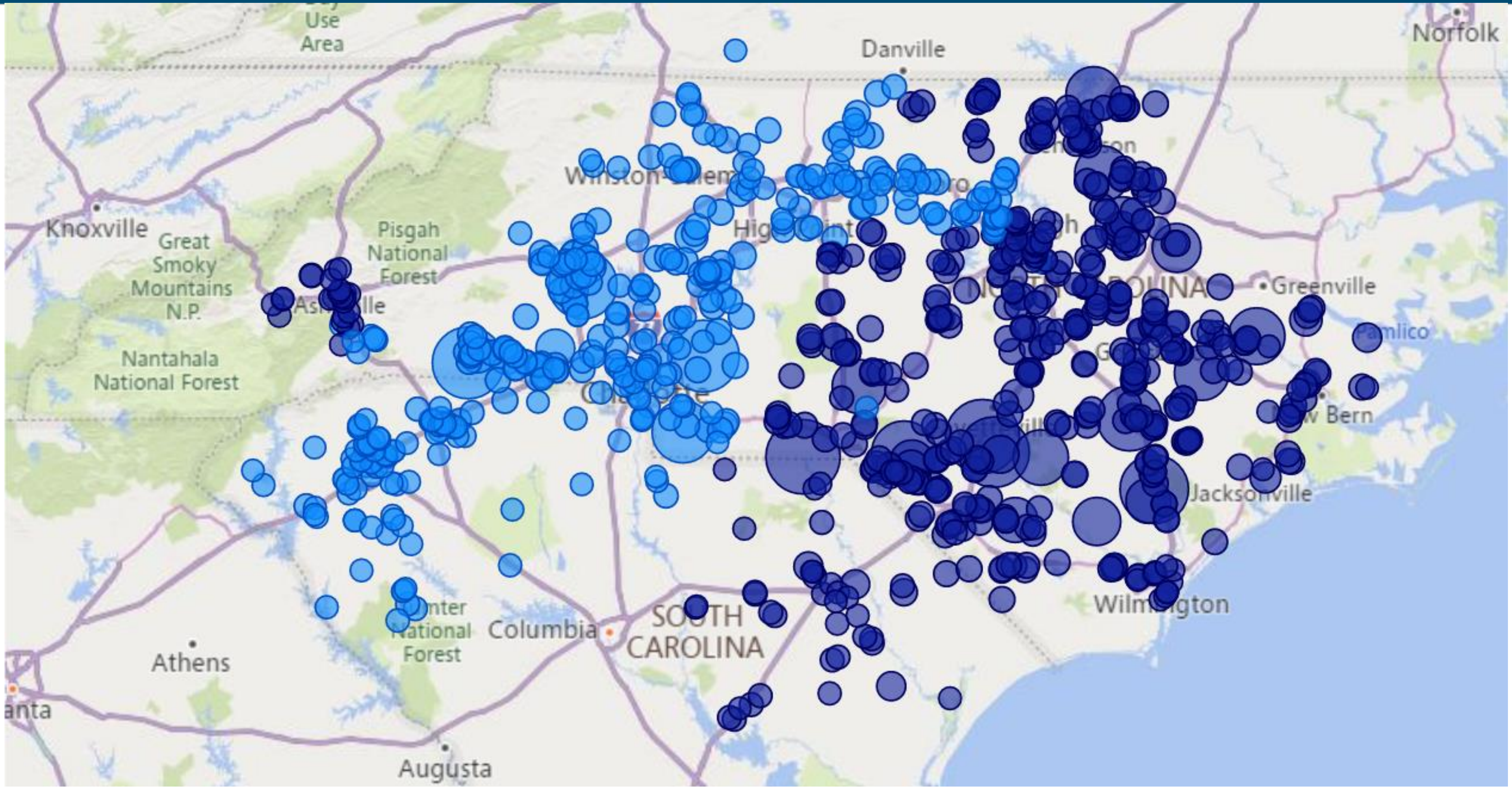




Distributed Resources by County



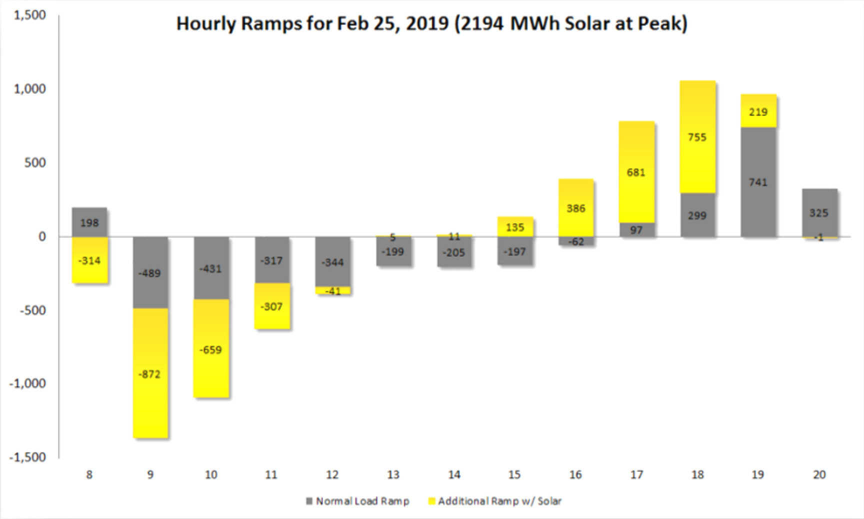
Geographical Overview of Sites in Duke Energy Progress

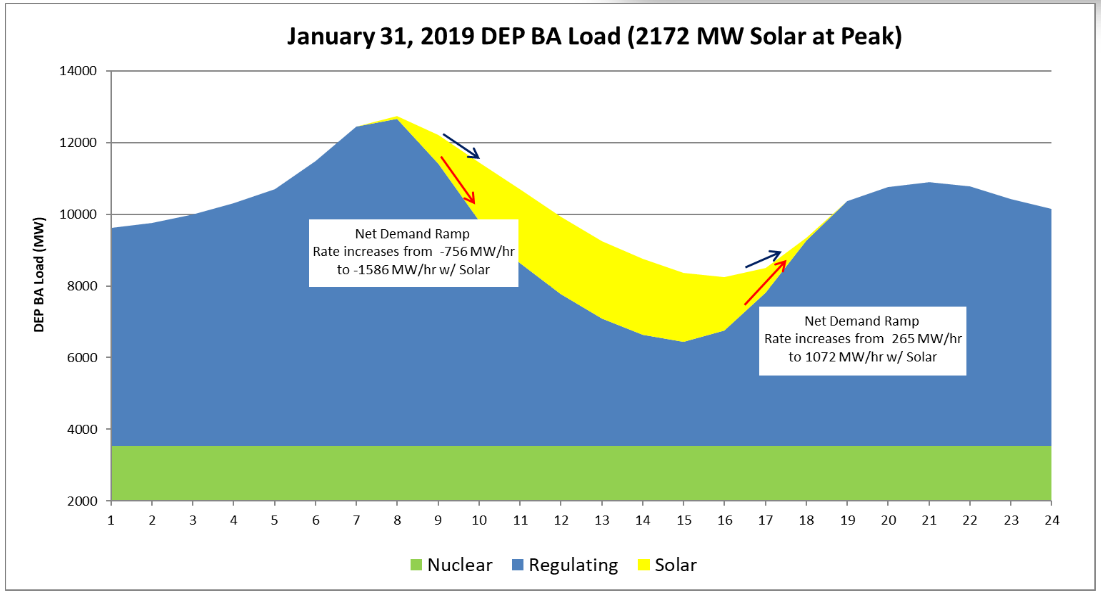


Situational Awareness

Hourly Ramps

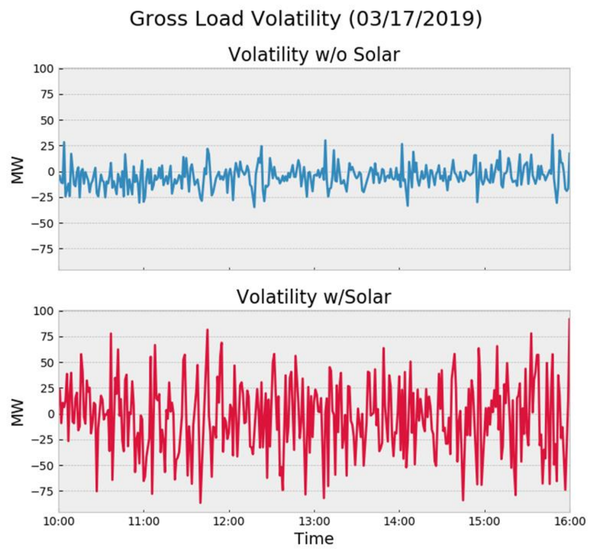
- In the winter, solar generation is negatively correlated to load
  - Increases while load is decreasing
  - Decreases while load is increasing
- Results in an additive hourly ramping effect for native resources increasing ramp requirements between 2X and 4X.

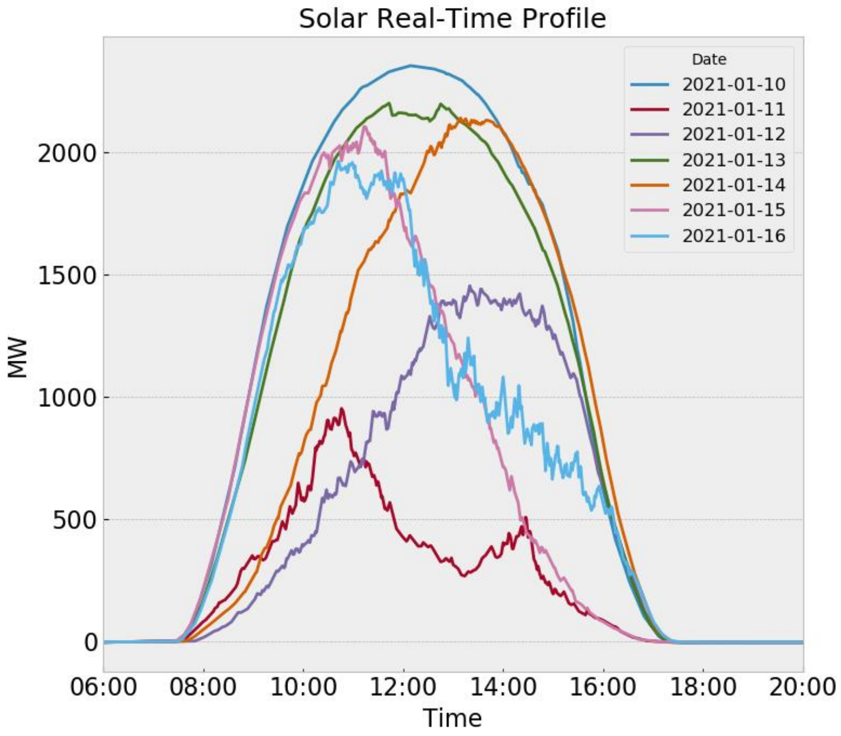




Ramp Rate Impacts

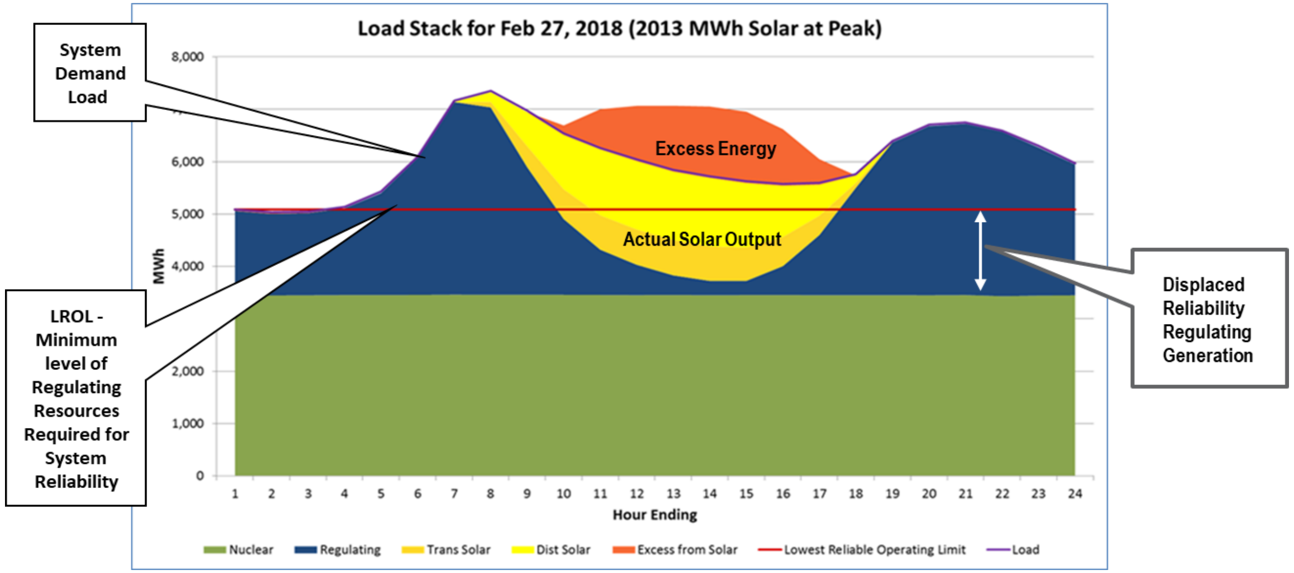
- Solar generation is incredibly intermittent
- Has doubled the regulation requirement from regulating resources
- Becomes more problematic during
  - Lighter loads
  - Higher solar penetrations



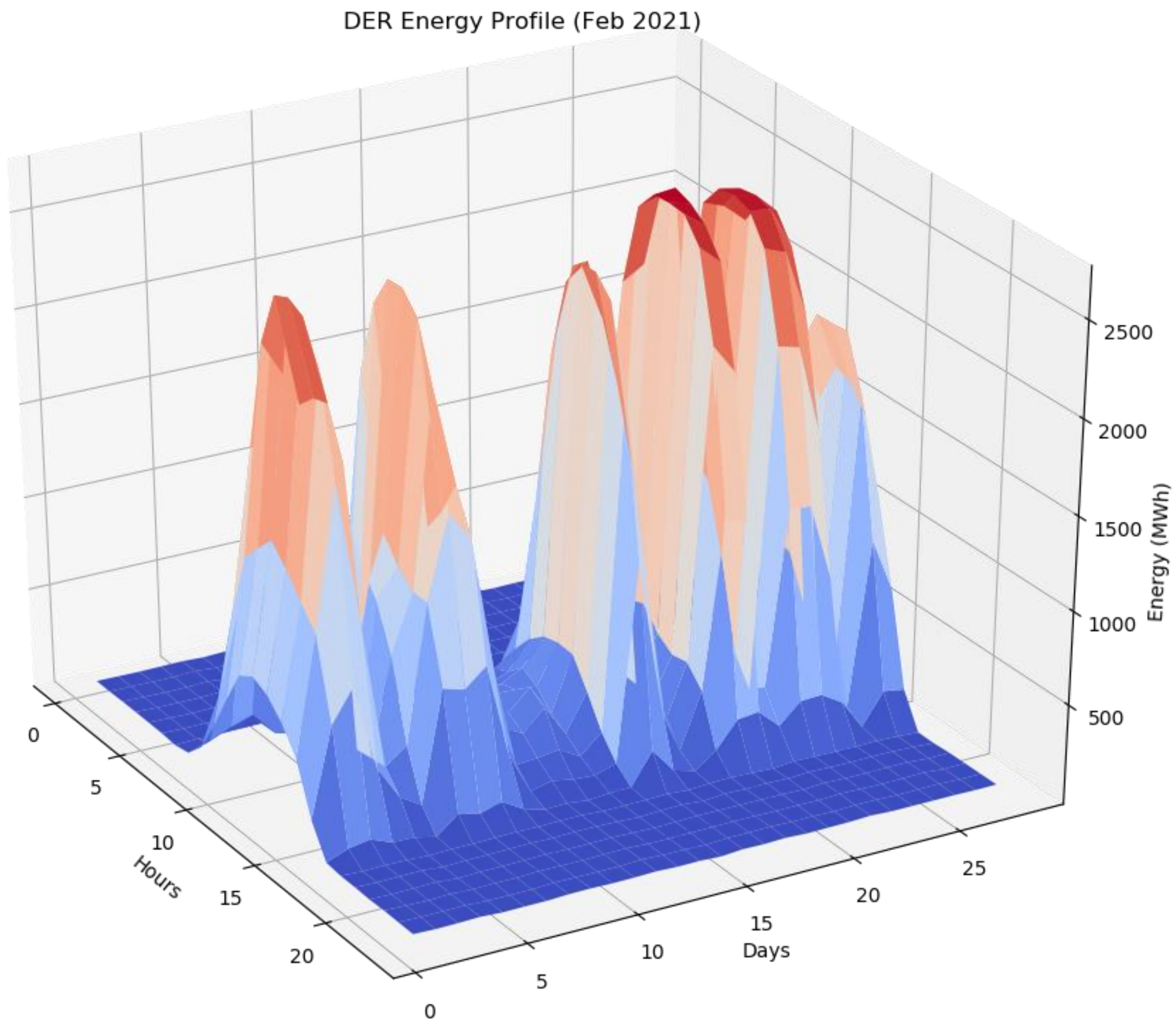


Unit Commitment Requirements

- Resource commitment has to manage new needs
  - Additional regulation response
  - Tighter startup windows for longer startup time resources.
- These new commitment profiles come with new concerns
  - Higher minimum generation thresholds
  - Different generation mix needed
  - More commits and de-commits from native resources
  - Excess Energy periods
- We established the Lowest Reliability Operating Limit (LROL)



Monthly Energy Profile



Operational Considerations

Generation

- Load Forecast
- Energy Accounting and Reporting
- AGC and System-Level Tuning
- Frequency Response
- Load Response Characteristics
- Momentary Cessation
- Energy-based economic dispatch

Network

- Transmission System Impacts
- State Estimation
- Power Flow
- Contingency Analysis
- Operational Planning Models
- Transmission Planning Models

EMS Modeling and Monitoring

BA and System Loads

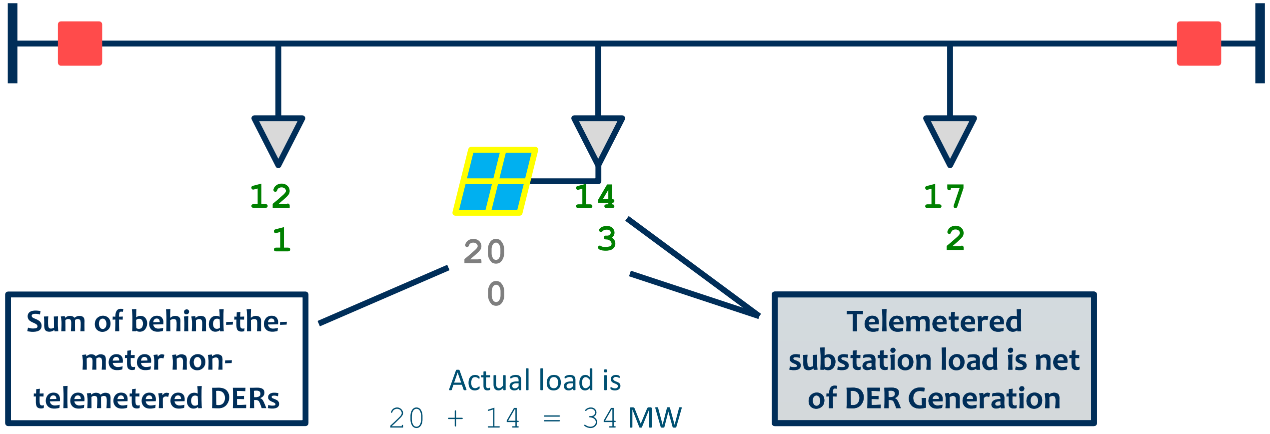
- Distributed energy telemetry or estimation is important for
  - Load calculation and forecasting
  - Unit commitment accuracy
  - Power flow and contingency analysis
  - Transmission and Operational Planning Analysis
- System-level loads are calculated, not measured

$$Load = \sum_{n=1}^{N} Gen_n - \sum_{t=1}^{T} Tie_t$$

- Missing generation results in lower calculated load

State Estimation Challenges

- Just because a substation is not feeding power into the transmission network, does not mean it is not impactful
- Impacts based on SE error tolerances for each substation
- If the load and DER are not separated
  - State Estimation will limit the amount they can change based on statistics
  - Scaling an injection as gross load will result in an incorrect P/Q result

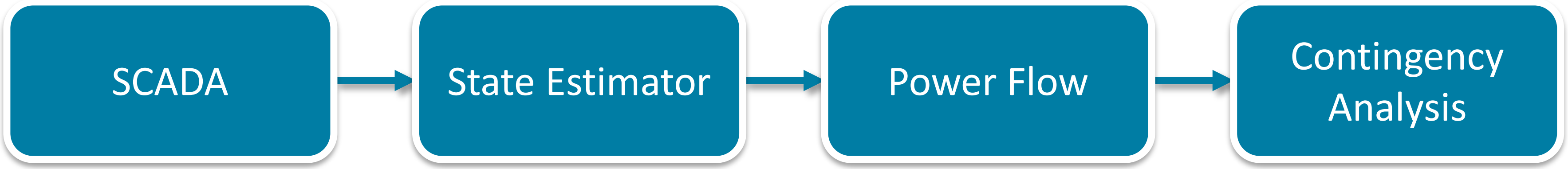


Transmission System Impacts

- DERs provide power offsets at delivery points (substations) that change
  - Need to be able to scale generation separate from load in models
  - Need different profiles for generation and load
- Must consider DER impacts on network load calculations
- Volt/VAR impacts from DERs
- Losses

State Estimation and Power Flow Overview

- Purpose of the State Estimator is to estimate the voltages and angles (state matrix) at every power flow bus
- The state estimator uses
  - Line flows
  - Transformer and substation loadings
  - Available bus voltages
- The voltages and angles are used by power flow applications
- Results of power flow applications are passed to contingency analysis applications

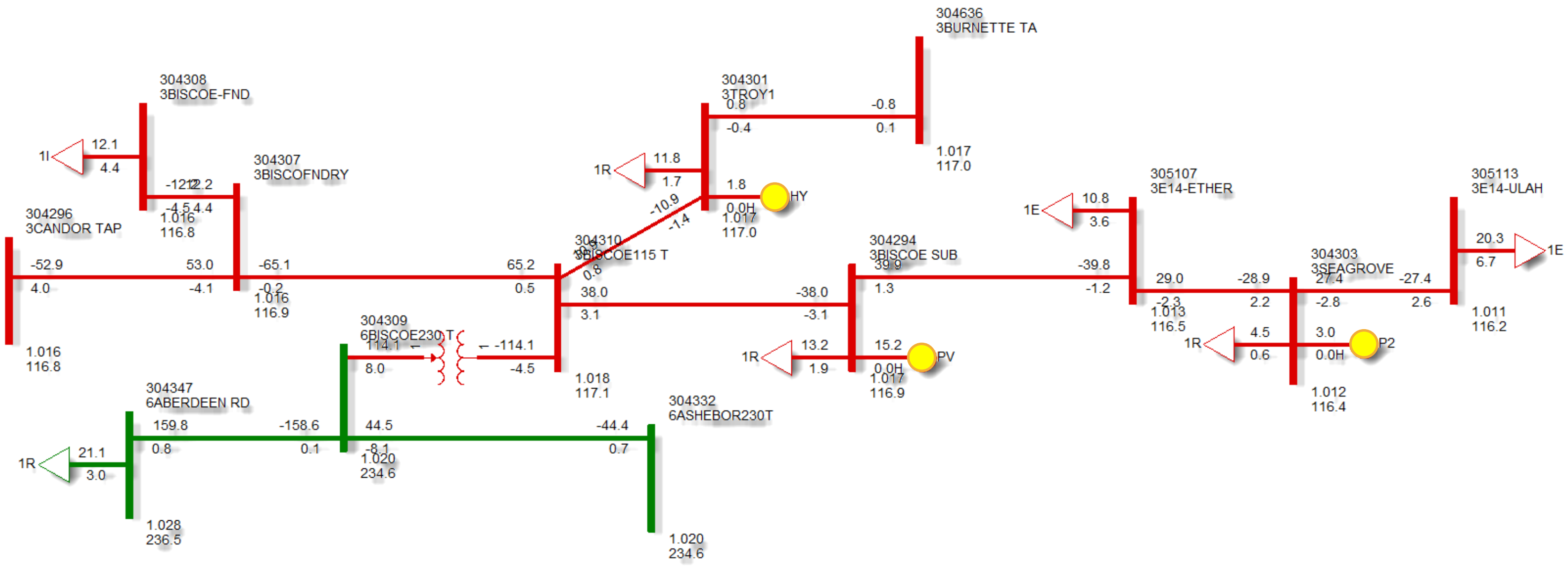


Future Considerations

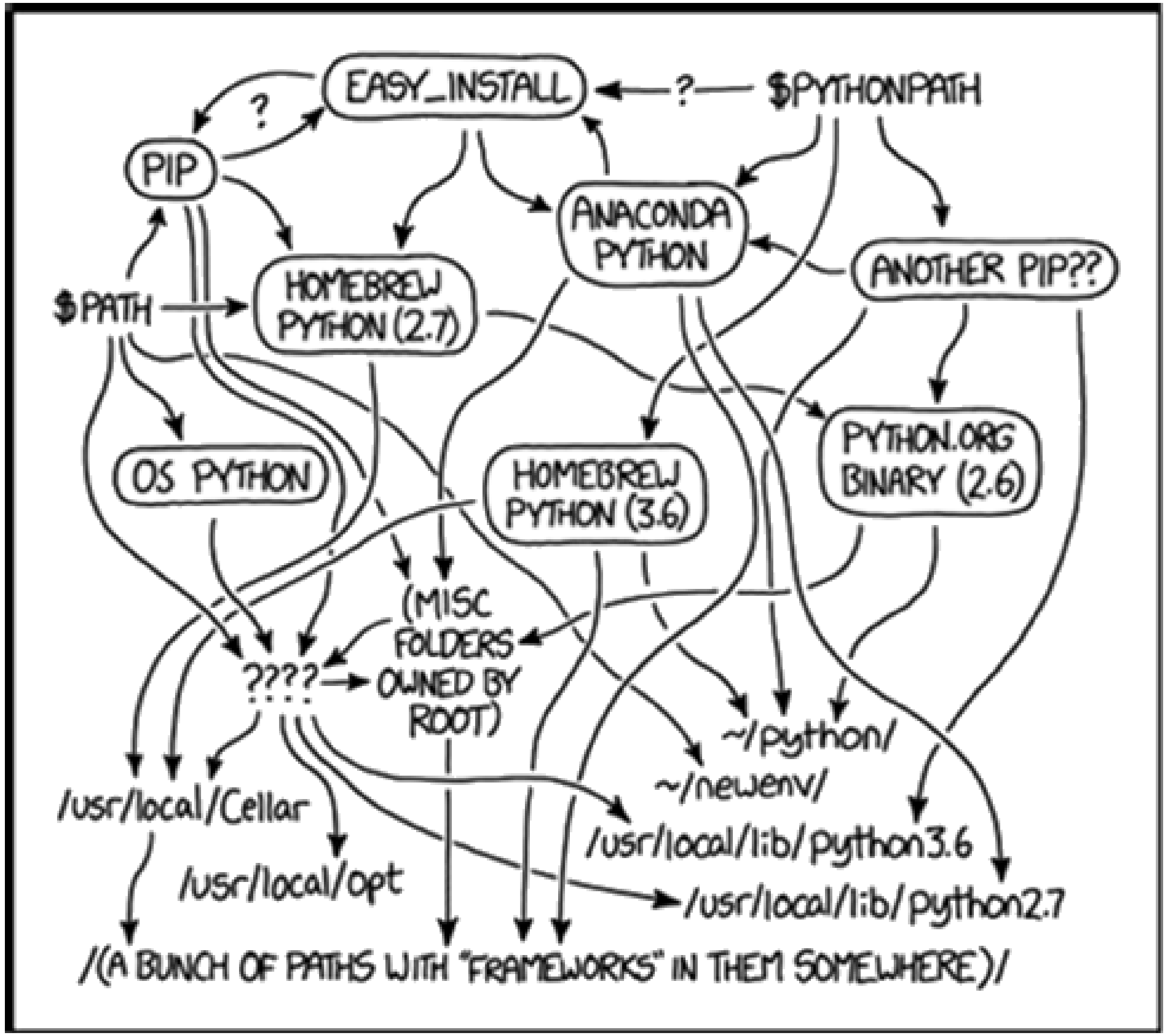
- AGC-level tuning needs
- Unit-level regulation response
- Economic dispatch that accounts for power *and* energy
- Breaking up load and DER into smaller load area groups
- Implementation of short-term forecasts for load and DER
- Projected Contingency Analysis

Transmission Power Flow Studies

- The resources are distributed in the model as they are in reality
- Injections from these resources drive local area power flows
- Failure to study them this way will result in unexpected loading conditions

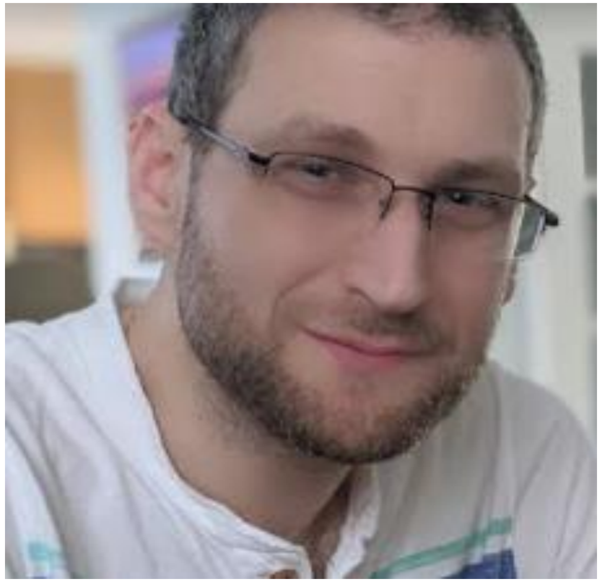


How it all works



Questions…

Daniel Moscovitz



Daniel Moscovitz is currently a senior lead engineer at PJM. He is responsible for real-time application support of PJM’s Network Applications tools and developing enhancements for future business processes improvement.

Mr. Moscovitz has earned a Bachelor of Science in Electrical Engineering from Bucknell University, a Master of Science in Electrical Engineering from Drexel University and is currently a PHD candidate at Temple University.

Session 2: DER

Daniel Moscovitz– Sr. Lead Engineer

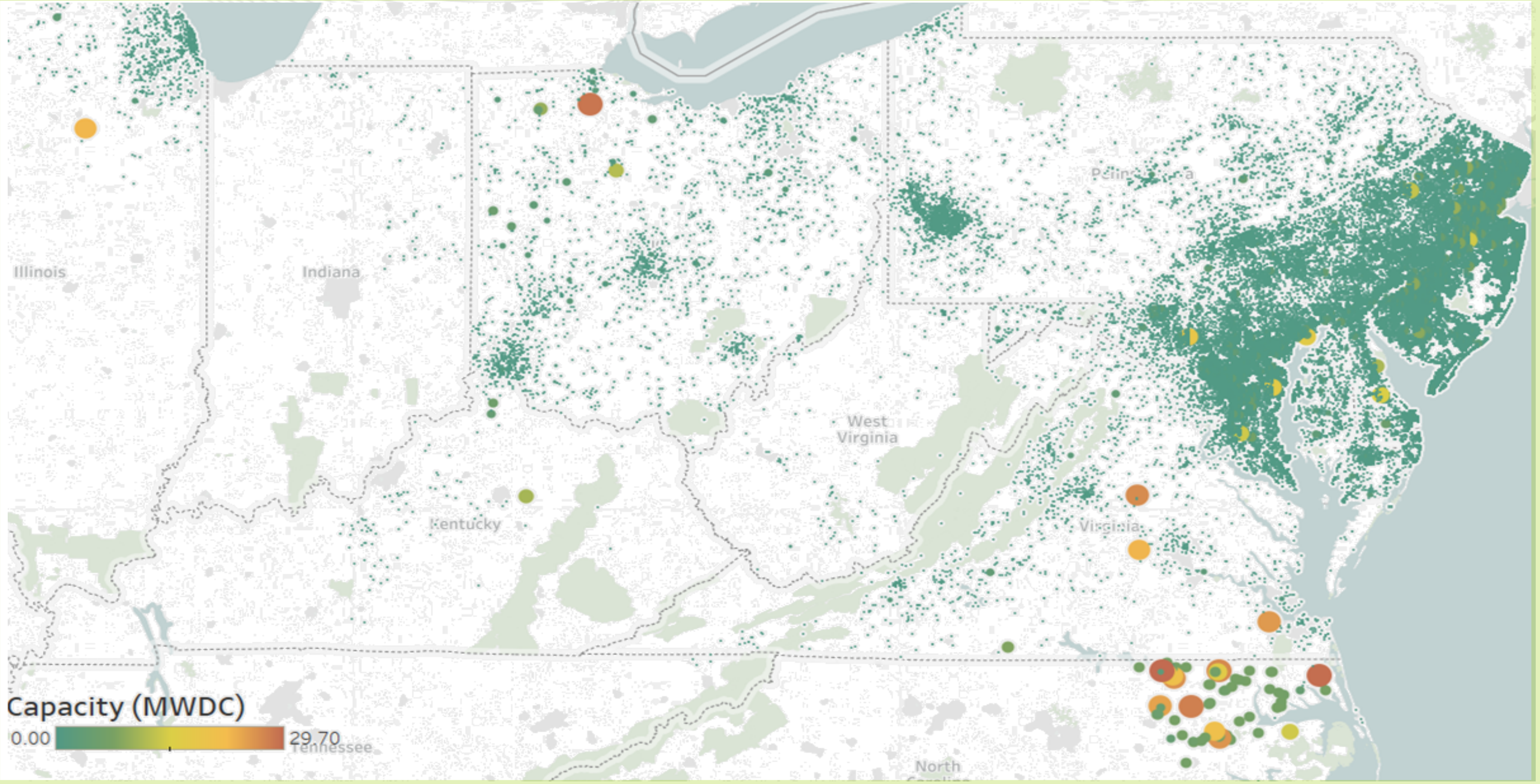
PJM Operations EMS Support

NERC Monitoring and Situational Awareness Technical Conference

October 7th 2021

Behind-the-Meter (BTM) Generation

- **Physically located behind a utility meter**
- **Does not participate in PJM wholesale markets**
- **Does not enter the PJM New Services queue**

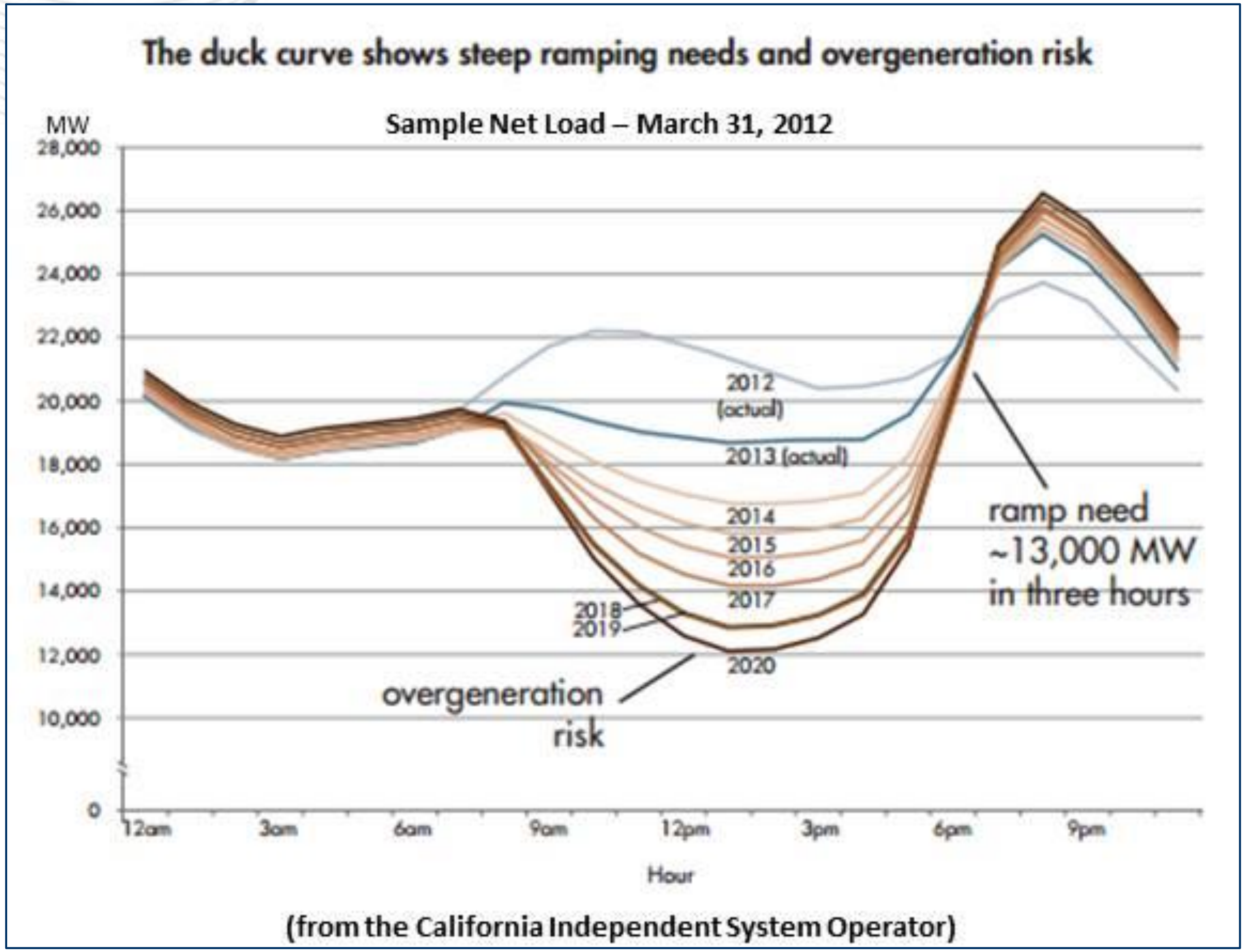


Challenges of Increased BTM Solar Penetration

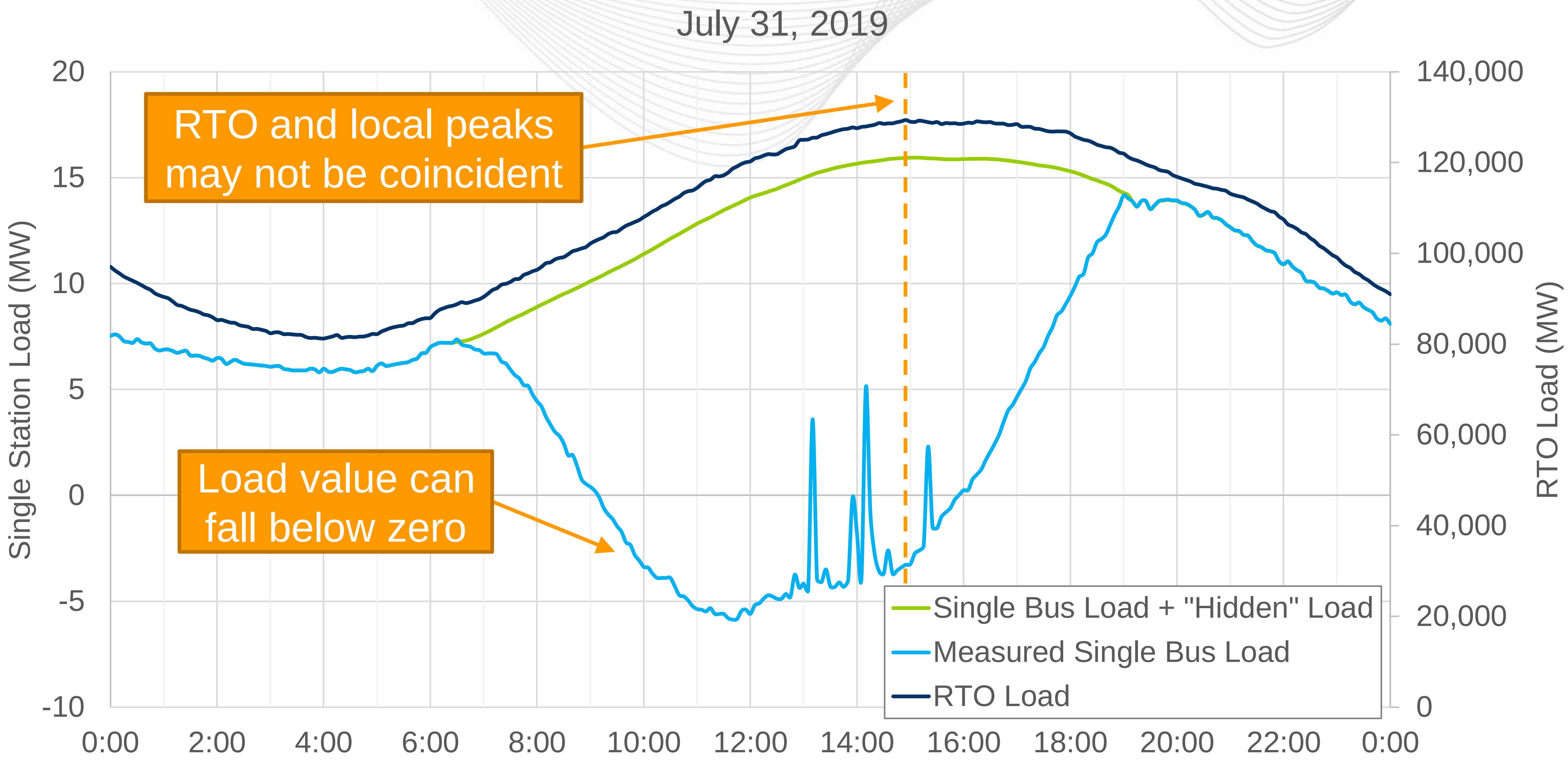
Load forecasting challenges

Transmission congestion risks

Increased flexibility needs

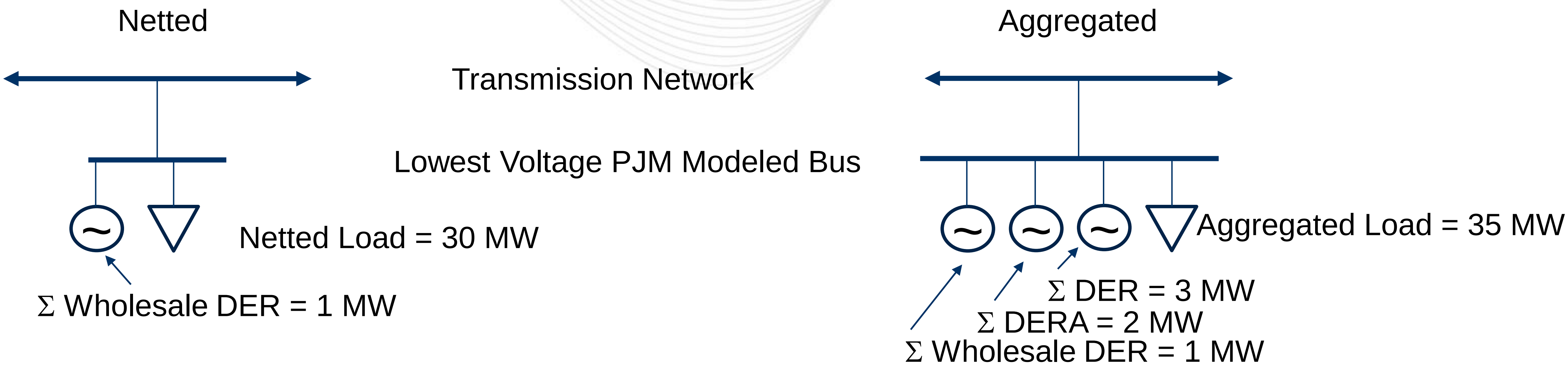


Need for BTM Data: Transmission Outage Analysis



Generation Modeling does not equal Visibility

Simplified Example of Netted and Aggregated Modeling



Implicit Modeling

- Evaluation Criteria for Modeling of BTM/DER in the EMS
- A distinction on the appropriate use of implicit vs. explicit modeling is necessary for this modeling strategy. A method of assigning DER units to-be-modeled into the implicit or explicit method will provide clarity and mitigate the challenges stated above.
- The general rule is: the distribution-connected resource must be both impactful and observable if it is to be explicitly modeled.

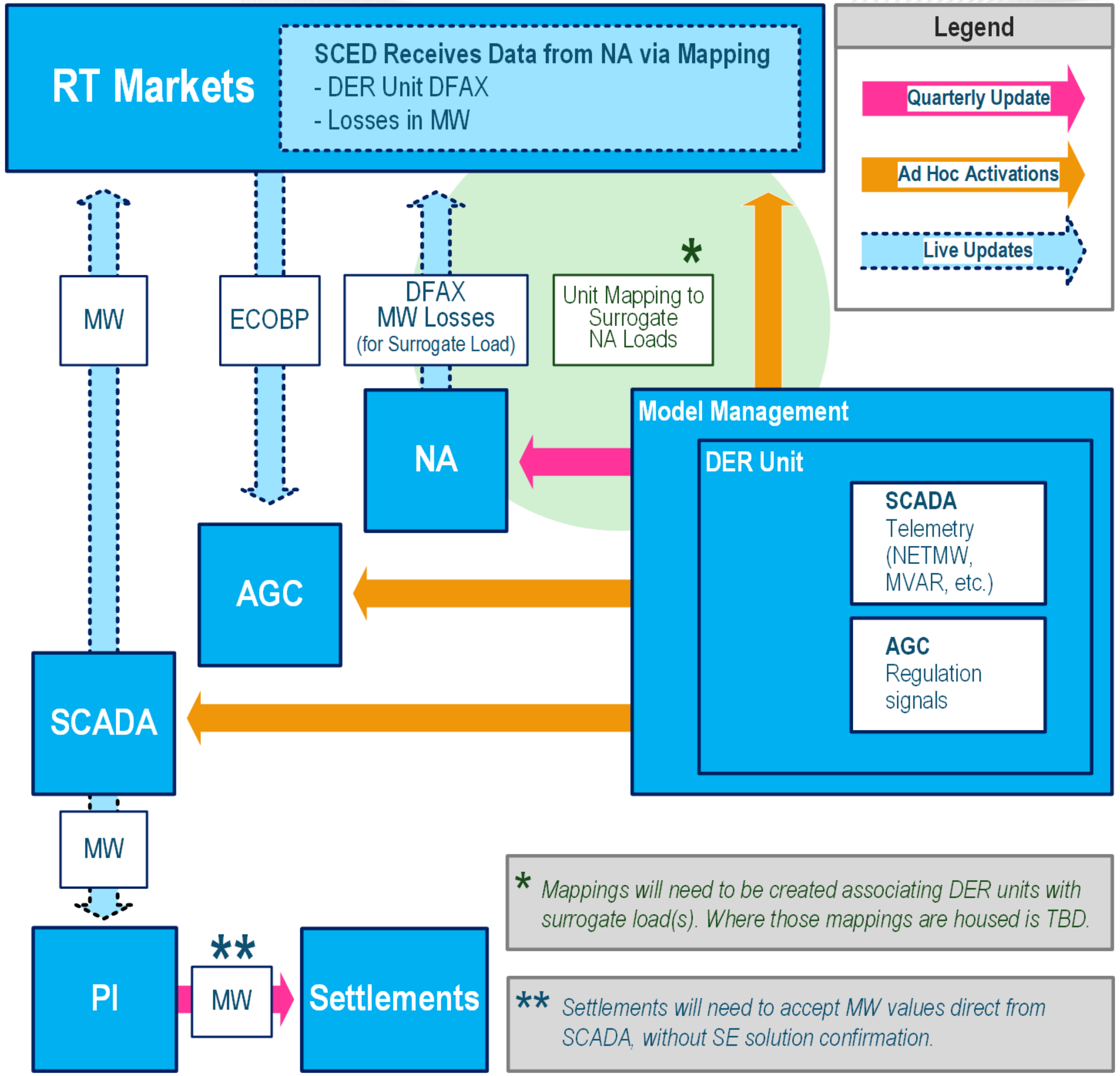
Impactful

- **Impactful** refers to the degree of electrical influence that a given DER unit (or DER aggregate) has on any PJM monitored constraint. In the past this has been quantified by the unit's MW capacity. However, because this class of units is separated from the BES by some level of distribution topology and because participation models are shifting, a MW threshold is overly simplistic. Constraint control is the multiplication of distribution factor (DFAX) between the generator and the constraint times maximum flow (PMAX) divided by the thermal rating of each PJM monitored element. The proposed criteria for impact is 1%. A generator that does not reach 1% impact on any PJM monitored element is considered not impactful in the context of our model.
- IF (DFAX)*(PMAX / RATING for ANY monitored element) > 1%, THEN Unit is Impactful
- Note that DFAX for a unit considering PJM interconnection can be evaluated using surrogate loads (weighted average for DER between PJM modeled substations) in the PJM model or against a more detailed planning representation (if available).
- Non-impactful generation can still impact PJM monitored elements in aggregate with other generation. The term "impact" is <u>not</u> intended to describe the economic behavior of the resource. In this context refers only to the impact of the generator on the explicit model. Implicit modeling still provides the needed information to economically dispatch the resource as explained in previous sections. This is not an evaluation of scale for participation in any PJM market.

Observable

- **Observability** is a concept from state estimation concerning the minimum number of measurements to determine the state variables in the power system equations. Measurement overlap is imperative to estimating both the system state and each measurement's error. Without sufficient overlapping measurements, power system state estimators add forecasted load measurements to determine a valid system state. While this leads to a mathematically stable solution, it can deviate from reality in these unobservable areas. An unobservable, more theoretical, estimation of the electrical area surrounding a DER resource does <u>not</u> permit verification or validation of the telemetered generation output. As such, implicit modeling provides an equivalent estimation of the system surrounding the resource without requiring the assumptions necessary for explicit representation.
- Control theory states observability analysis of a linear time-invariant system depends not only on the measured state of the individual device but of other nearby networked devices. As such, the generation owner cannot provide sufficient data for observability from their own area of ownership. Without sufficient measurements from the generator **and** the surrounding network, the generation will be unobservable.
- Nearby measurements include line telemetry, voltage measurements, transformer flows, and other state based data like breaker/disconnect status, transformer tap positions, and shunt status information. Limited availability of these types of telemetry on distribution systems leads to distribution voltage interconnected generators generally being unobservable.

Implicit Modeling



* *Mappings will need to be created associating DER units with surrogate load(s). Where those mappings are housed is TBD.*

** *Settlements will need to accept MW values direct from SCADA, without SE solution confirmation.*

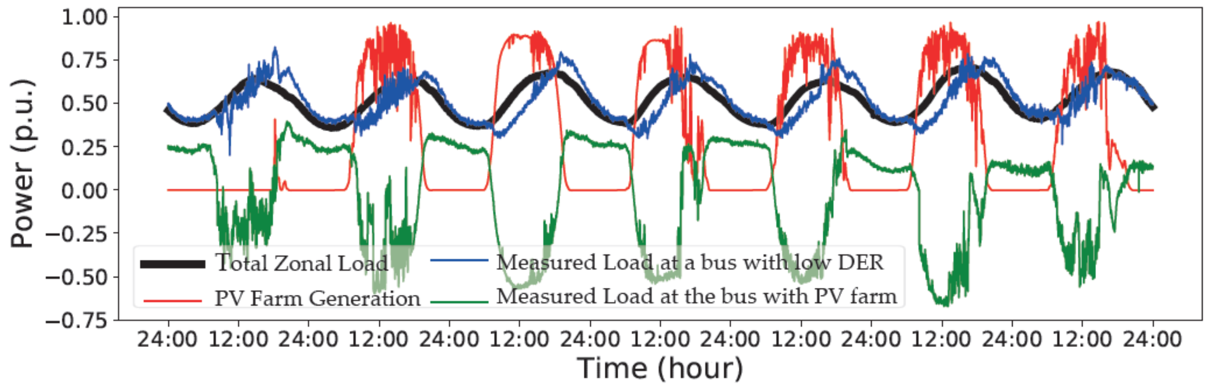


Fig. 2. Illustration of real-world pre-processed, minute-level, normalized, and anonymized utility data.

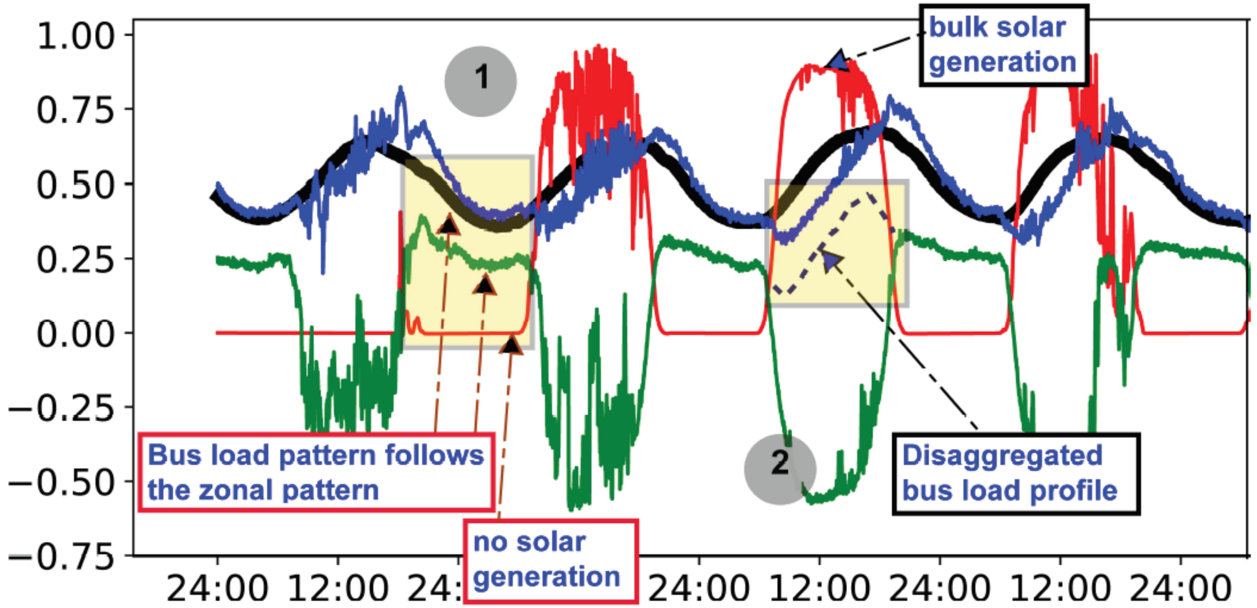


Fig. 3. Non-intrusive data-driven disaggregation of load profiles with two scenarios illustrated.

MVAR’s

- Generators that are connected at a high electrical distance from the closest BES bus have greatly reduced utility for direct voltage support of the BES as compared to an identical asset connected to the BES. Long lengths of lower voltage lines, distribution capacitor banks or other distribution devices, other distribution loads or assets, can all act to dissipate, consume and otherwise obfuscate the MVAR output of those generators as seen by the nearest BES bus. While PJM will often still obtain and parameterize the reactive capability of such units in EMS applications, this is done out more out of best practice than any immediate critical use of the data.

- Macro trends in the overall reactive loading of the distribution system is not unimportant or inconsequential. Overall, more MVAR production in distribution will lower the amount of MVARs pulled from or required from the BES, even if at a diminishing proportionality as more MVARS are consumed in distribution electrical distance than otherwise would be if delivered at the BES. But generators connected at high electrical distance will not be observable, in the sense that PJM will not be able to reliably verify the MVAR output as it impacts the BES, and will not be practically operable or dependable for BES voltage support since the POI output will largely dissipate before impacting the target BES areas of concern.

- BES voltages that PJM operates to will have significant impact on distribution voltages and operations. However that electrical relationship does no confer PJM with any direct observability of or role to secure distribution voltages, as EDCs have separate systems and methodologies to operate to their target voltages largely independent of PJM.

10 minute Break

Kristin Swenson

Kristin Swenson began her energy career in project development for industrial-scale wind, which grew to include renewable construction, investor management, forecasting and performance optimization, project finance, commercial energy contracts, and market operations.

She has experience in renewable energy project origination, development and permitting at the state, provincial, and Federal level, as well as contract negation including management of detailed technical issues. Kristin has managed asset operation in the US and Canada, working on facilities in ERCOT, MISO, PJM, CAISO, Quebec, Ontario, and Manitoba.

NERC M&SA Conference
DER Order 2222

October 7, 2021

Kristin Swenson
DER Program Manager

Purpose & Key Takeaways

Purpose: Review MISO's O2222 compliance filing progress on key questions

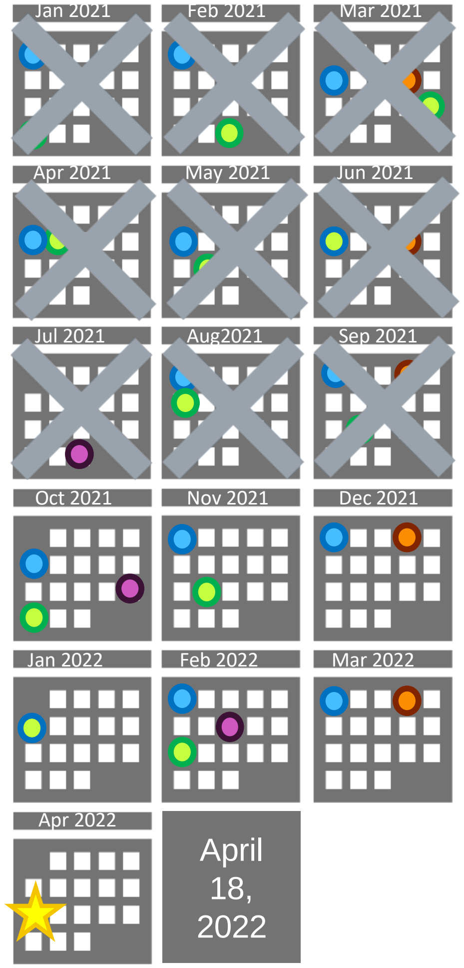
Key Takeaways:

- MISO is recommending single EP Node aggregations
- Data requirements haven't been finalized
- MISO expects any requirements to evolve with higher penetration of distribution-located assets

MISO filed, and was granted, a Motion for Extension of Time to file our compliance plan with FERC

A	Commission Jurisdiction and General Requirements
B	Definition of DER and DERA
C	Eligibility to Participate in RTO/ISO Markets through a DERA
D	Locational Requirements
E	Distribution Factors and Bidding Parameters
F	Information and Data Requirements
G	Metering and Telemetry Requirements
H	Coordination between the RTO/ISO, Aggregator, and Distribution Utility
I	Modification to List of Resources in Aggregation
J	Market Participation Agreements

- DER Task Force
- Market Subcommittee / Present Design
- Electric Distribution Company Workshop
- FERC Filing



Upcoming Meetings:

- October 11 – EDC Workshop
- October 22 – RERRA Workshop scheduled
- November 1 – DER Task Force
- November 2 – EDC Workshop
- November 29 – DER Task Force
- December 1 – Market Subcommittee

FERC has called for collaboration across jurisdictions and seams; successful implementation requires developing new frameworks

MISO has the Facilitation Role in Order 2222

Review/Approve

Operate

Relevant Electric Retail Regulatory Authority/ Public Utility Commission (PUC)

- Define local interconnection requirements
- Assign any cost allocation/ recovery of upgrades
- Dispute resolution
- Review wholesale market participation eligibility for DERA
- Establish small utility opt-in
- Supervise applicable integrated resource planning process

Transmission Owner (TO)

- Understand DER flows at EPNode level
- Plan reliable trans-mission system
- Evaluate trans-mission system upgrades
- Coordinate transmission – distribution interface

MISO

- Enable participation in all markets
- Model, recognize, and value impacts on transmission system
- Maintain reliability on transmission system
- Coordinate with DERA, EDC, TO and RERRA
- Dispute resolution

Local Balancing Authority (LBA)/ Load Serving Entity (LSE)

- Manage day-to-day system operations
- Represent the EDCs in the DERa enrollment review

Electric Distribution Company (EDC)

- Evaluate DER flows and impacts on distribution systems' reliability
- Coordinate T&D interface
- Manage DER interconnection
- Coordinate communication with DERA and RTO
- Review DERa enrollment compatibility

DER Aggregator

- Register with the ISO, providing required data on DER location, configuration, telemetry, and performance capability
- Participate in wholesale market based on applicable wholesale and retail rules
- Coordinate communication with RTO and EDC

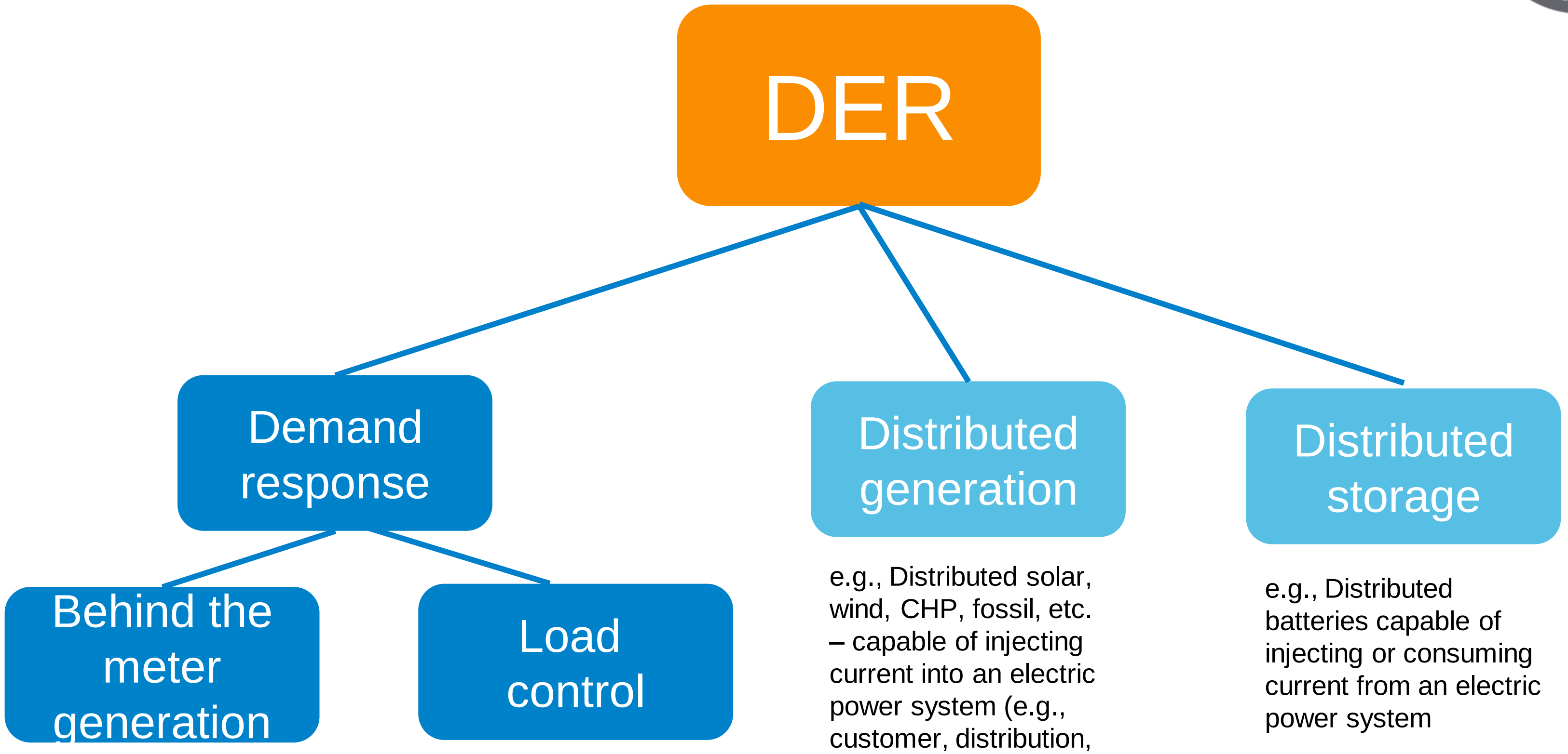
Key Requirements of FERC 2222: Definition of DER and DERA

A “DER” is defined as “ ‘any resources located on the distribution system, any subsystem thereof or behind a customer meter.’ These resources may include, but not limited to, resources that are in front of and behind the customer meter (e.g., customer sites capable of demand reduction), electric storage resources, intermittent generation, distributed generation, demand response, energy efficiency, thermal storage, and electric vehicles and their supply equipment.” *O2222, P 114*

A “DER Aggregator” (DERA) is defined as “an entity that aggregates one or more distributed energy resources for purposes of participation in the capacity, energy and/or ancillary service markets of RTO/ISOs.” *O2222, P 118*

“DERa” is defined as an aggregation of DER

DER Taxonomy



e.g., On-site customer generation for the sole purpose of load reduction

e.g., Controllable load not capable of injecting current into any electric power system

e.g., Distributed solar, wind, CHP, fossil, etc. – capable of injecting current into an electric power system (e.g., customer, distribution, or transmission electrical systems)

e.g., Distributed batteries capable of injecting or consuming current from an electric power system

FERC definitions (18 CFR § 35.28(b)(4)&(5):

Demand response means a reduction in the consumption of electric energy by customers from their expected consumption in response to an increase in the price of electric energy or to incentive payments designed to induce lower consumption of electric energy.

Demand response resource means a resource capable of providing demand response.

NEW

How will DERa be represented in markets, operations, & planning models?

Representative aggregate generator which can have a positive or negative capability. Maintain current representation of the Transmission/ Distribution (T/D) interface. A new DERa market resource model will be created with a single EPNode/ CPNode designation

MISO is creating a number of Use Cases to further demonstrate and describe the modeling of DER aggregations:

Aggregation Birch: 2MW of demand response (controllable water heaters and air conditioners), 1MW nameplate storage, 2MW diesel generator which is not solely for serving on site load, 1MW rooftop solar

Sample Modeling:

- One DERa resource capable of providing up to 6 MW (EPNode)
- DERa resource capable of withdrawing up to 1 MW
- DERA registers with one CPNode linked to EPNode

DRAFT: Excerpt commercial model requires DERa information

Information	Description
Unit EPNode	Representation in the Operations Models [U (Control Area) (Station) (Unit_ID)]
CPNode Name	Cannot exceed 14 characters
Minimum Output	Value is a number (MW). This can be negative number to account for charging potential
Maximum Output	Value is a number (MW)
Maximum Nameplate	Value is a number (MW). Represents the installed capacity of the DERa
Default Ramp Rate	Value is a number (MW)
Energy	Whether the resource can offer Energy in MISO market, (Yes/No)
Regulation	Whether the resource can offer regulation reserves in MISO market, (Yes/No). If Yes, Spinning and Supplemental are by default Yes
Spinning	Whether the resource can offer spinning reserves in MISO market, (Yes/No). If Yes, Supplemental is by default Yes
Supplemental	Whether the resource can offer on-line supplemental reserves in MISO market, (Yes/No)
Unit Type	DERa
Fuel Type	DERa

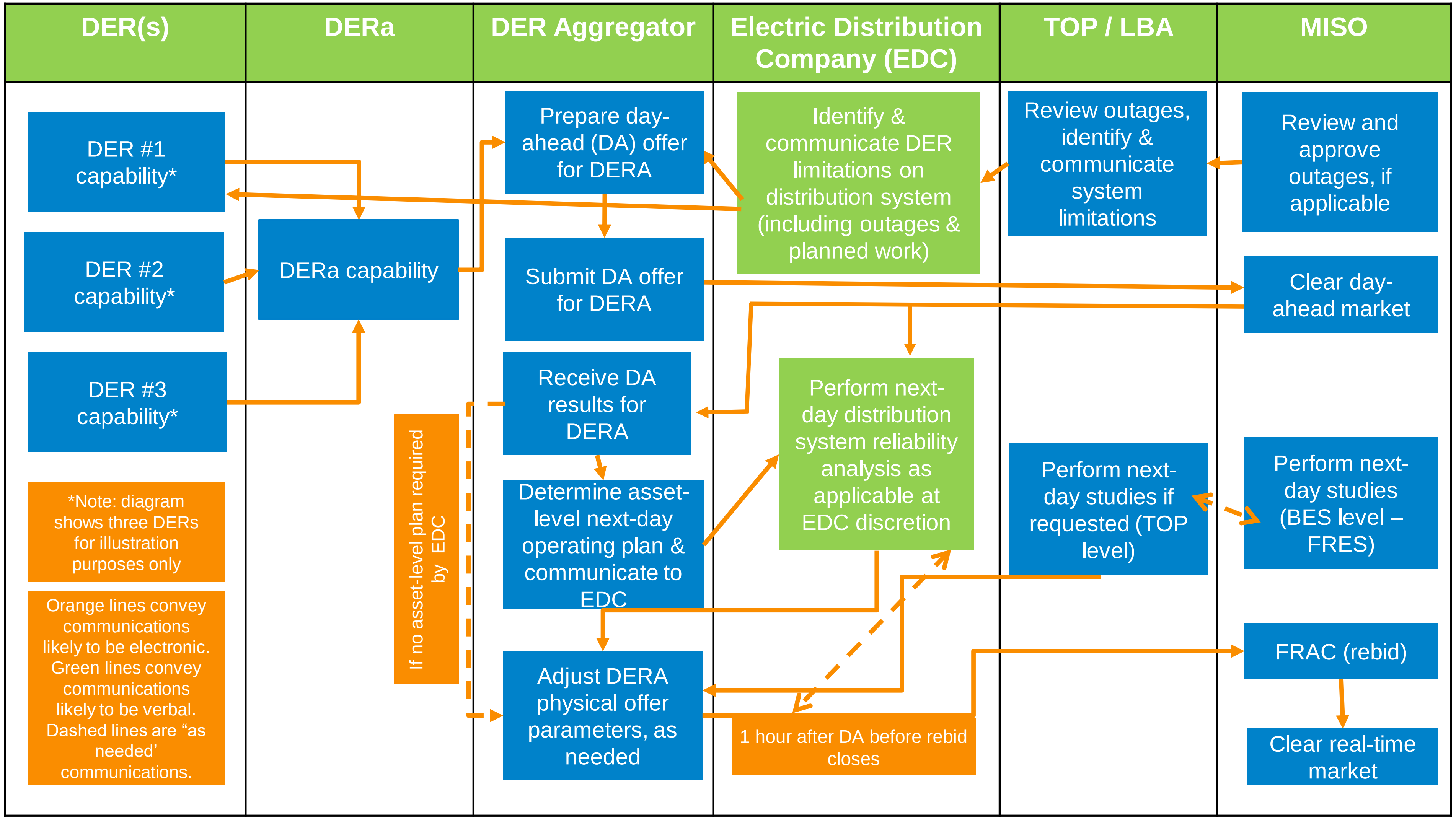
DRAFT: Energy Market requires real-time DERa data for participating

Information	Description
Aggregate Control Mode	Current control mode of the DERa
Resource Aggregate Output (MW)	The MW output of the DERa
Resource Aggregate Output (Mvar)*	The Mvar output of the DERa*
Resource Breaker Status	DERa representative breaker status to indicate availability of the DERa
Echo Resource Setpoint Measurement	Echo the received setpoint for the DERa. Allows MISO to verify that the setpoint was received

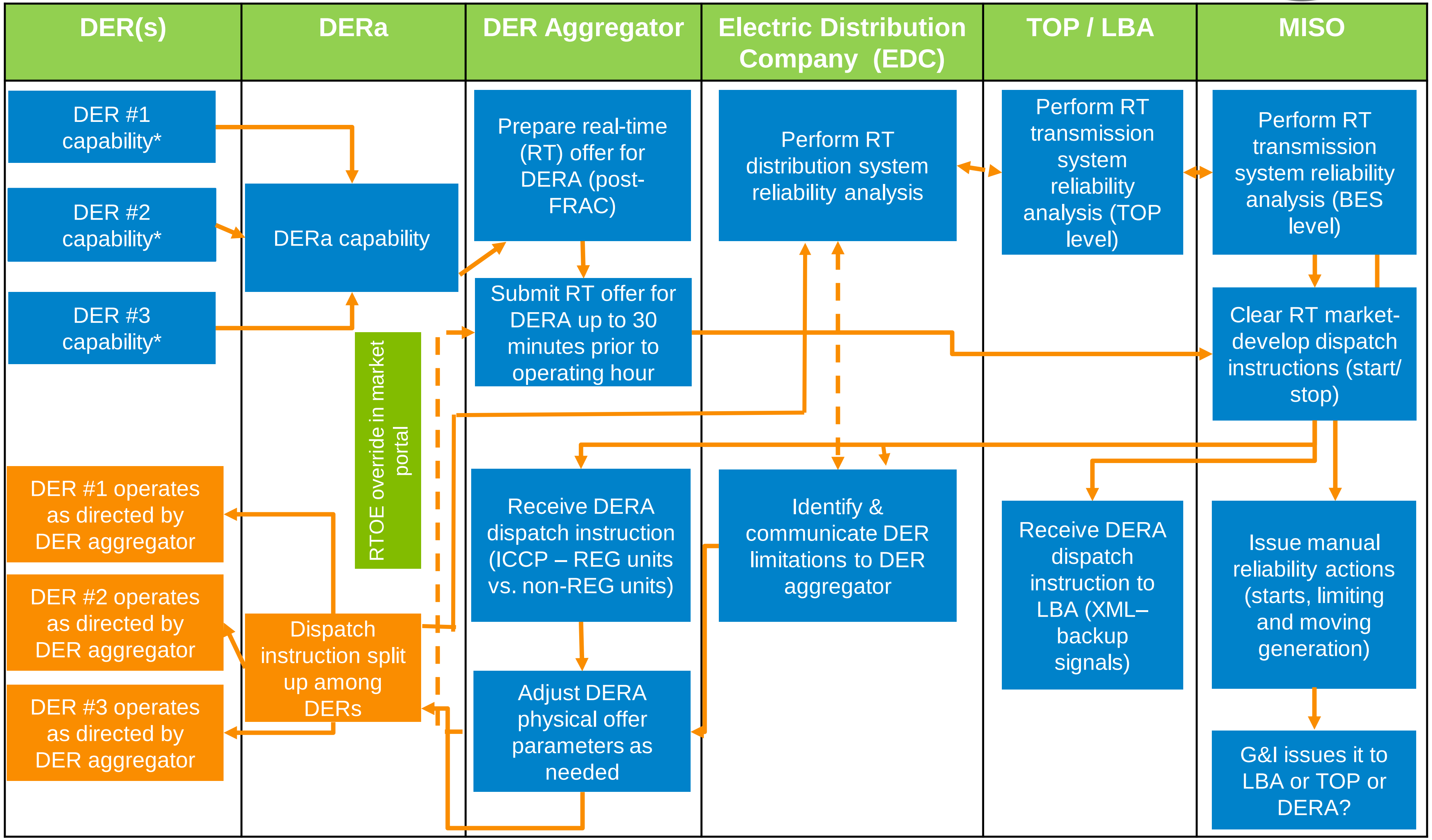
- MISO and our regional Electric Distribution Companies may have different data requirements for DER
- The MISO stakeholder process has not yet yielded a firm proposal on data requirements

Coordination Communication Paths

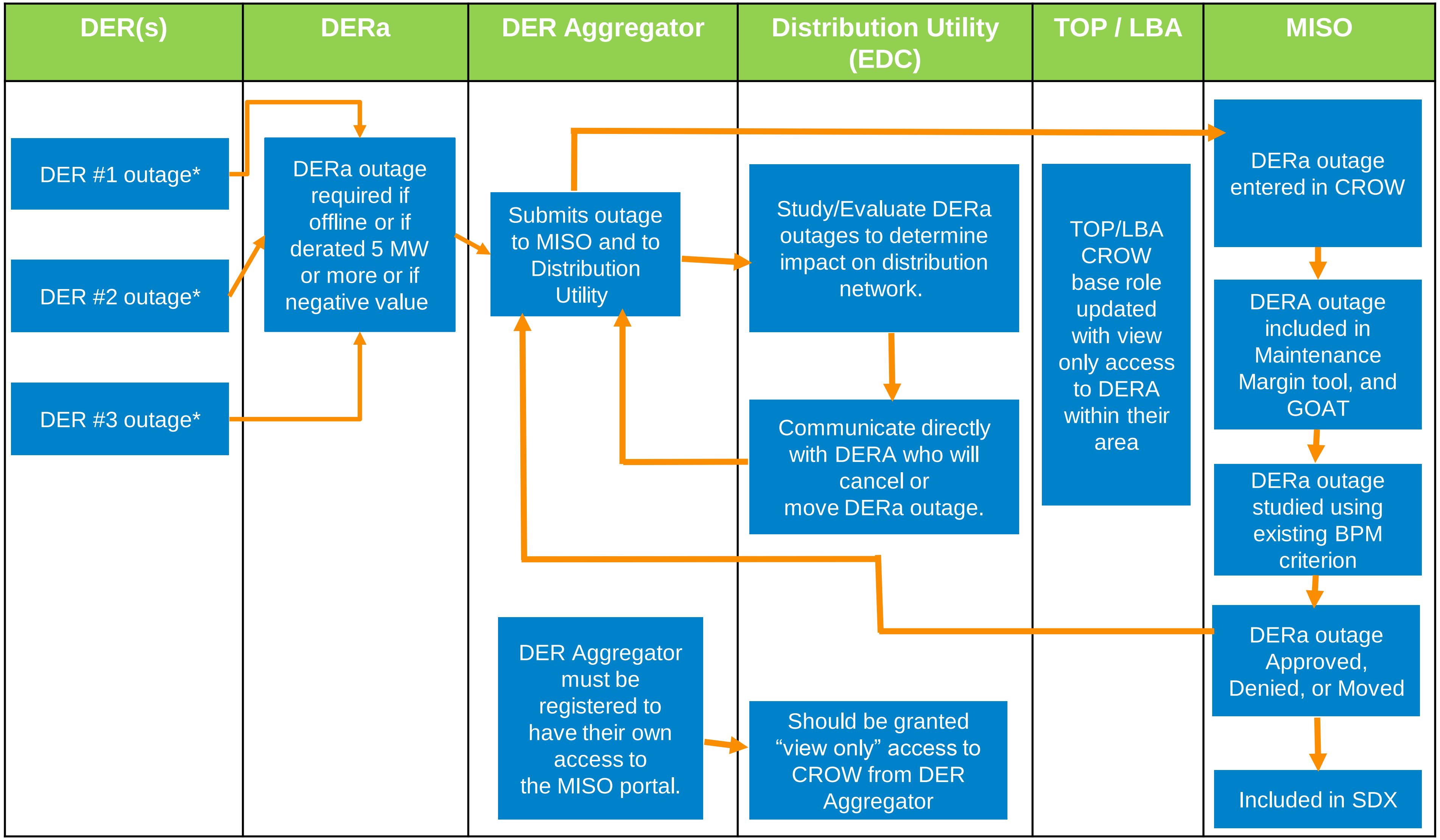
MISO Day-Ahead Operational Coordination



MISO Real-Time Operational Coordination



MISO Outage Coordination - Prior to Day-Ahead Market Close



Kristin Swenson
DER Program Manager
derprogrammanagement@misoenergy.org

DER Task Force meets monthly through April 2022
Details on the MISO Stakeholder Calendar
misoenergy.org

Ankit Mishra

Ankit Mishra is the currently serving as the Manager of the Market Engineering and Network Applications Support group at California ISO. Prior to this role, Ankit has held several technical management roles in his career spanning over 15 years at California ISO and PJM Interconnection.

Ankit holds a MBA degree from University of Illinois, a Master of Science degree in Electrical Engineering from Arizona State University. He is passionate about evolving grid and market operations by incorporating new tools and technologies

Modeling Distributed Energy Resources in CAISO systems

Ankit Mishra

NERC, M & SA, 10/07/2021

California ISO

Within its balancing authority area, the California ISO:

- Maintains reliability on the grid
- Manages the flow of energy
- Oversees the transmission planning process
- Operates the wholesale electric market

For much of the western U.S., the ISO:

- Operates the Western Energy Imbalance Market (EIM)
- Serves as Reliability Coordinator (RC West)

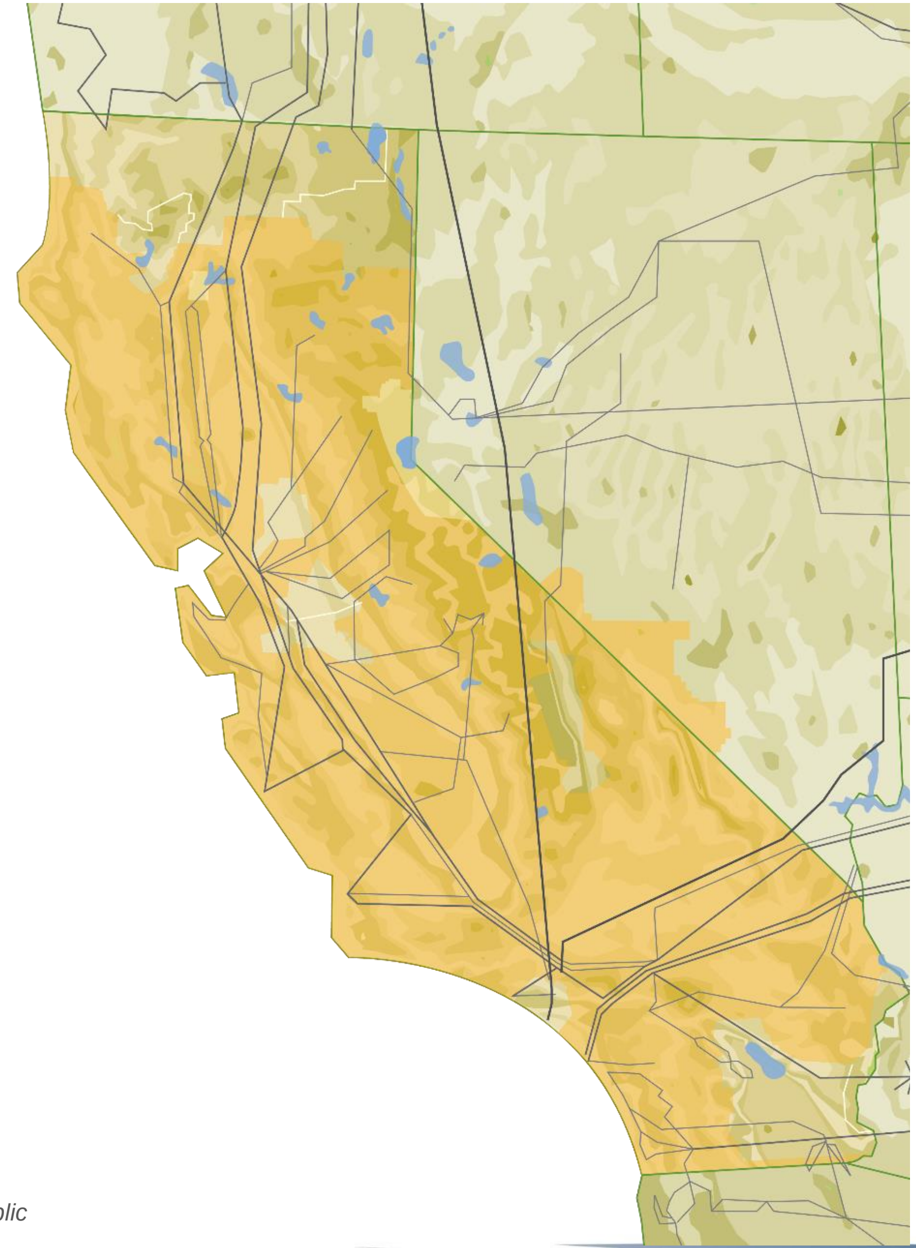
California ISO facts

26,000 circuit-miles of transmission lines

$10.8 billion annual market (2018)

78¢ per MWh grid management charge (June 1, 2020)

33,617 market transactions per day (2020)

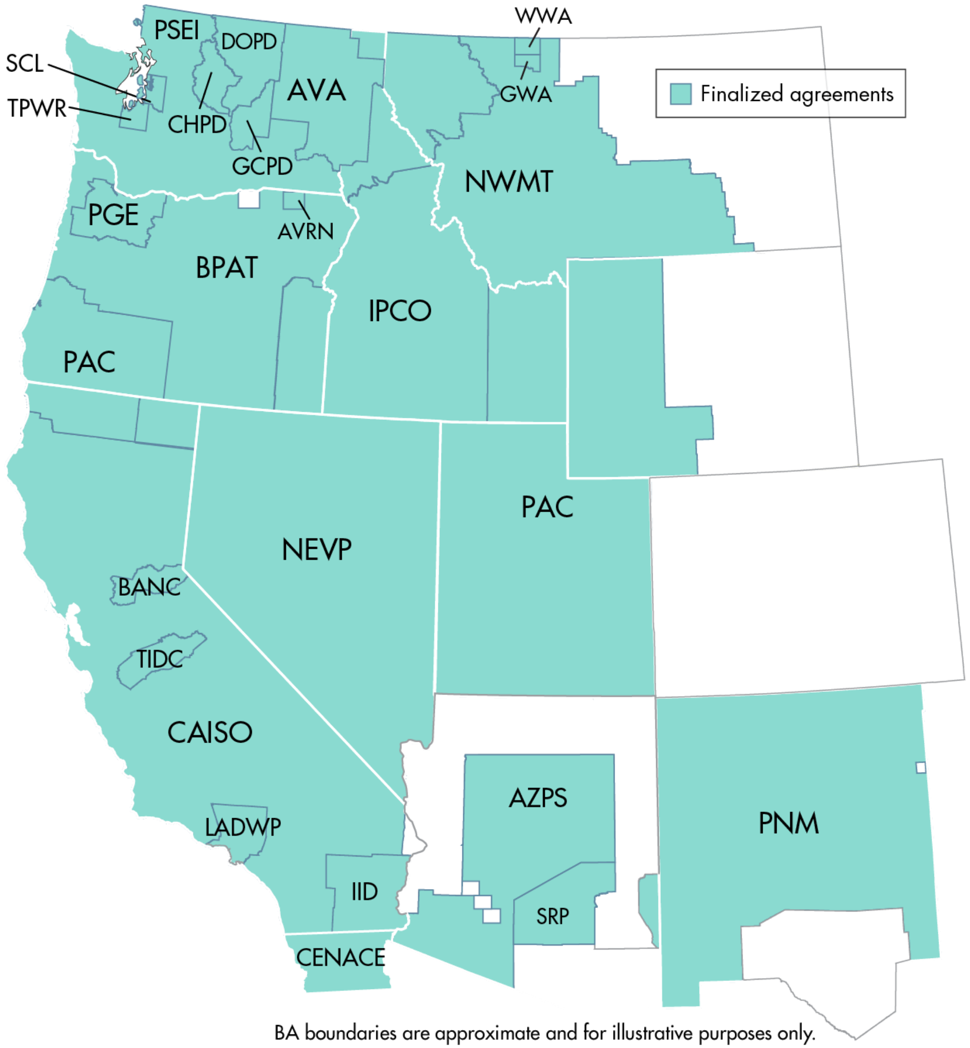


RC West

The ISO became the reliability coordinator for the majority of the Western Electricity Coordinating Council (WECC) in 2019.

Reliability coordinators:

- Have authority and responsibility for grid stability
- Monitor the interconnected grids in the West for compliance with federal and regional standards
- Authorize measures to prevent or avoid system emergencies in day-ahead or real-time operations
- Lead system restoration following major incidents

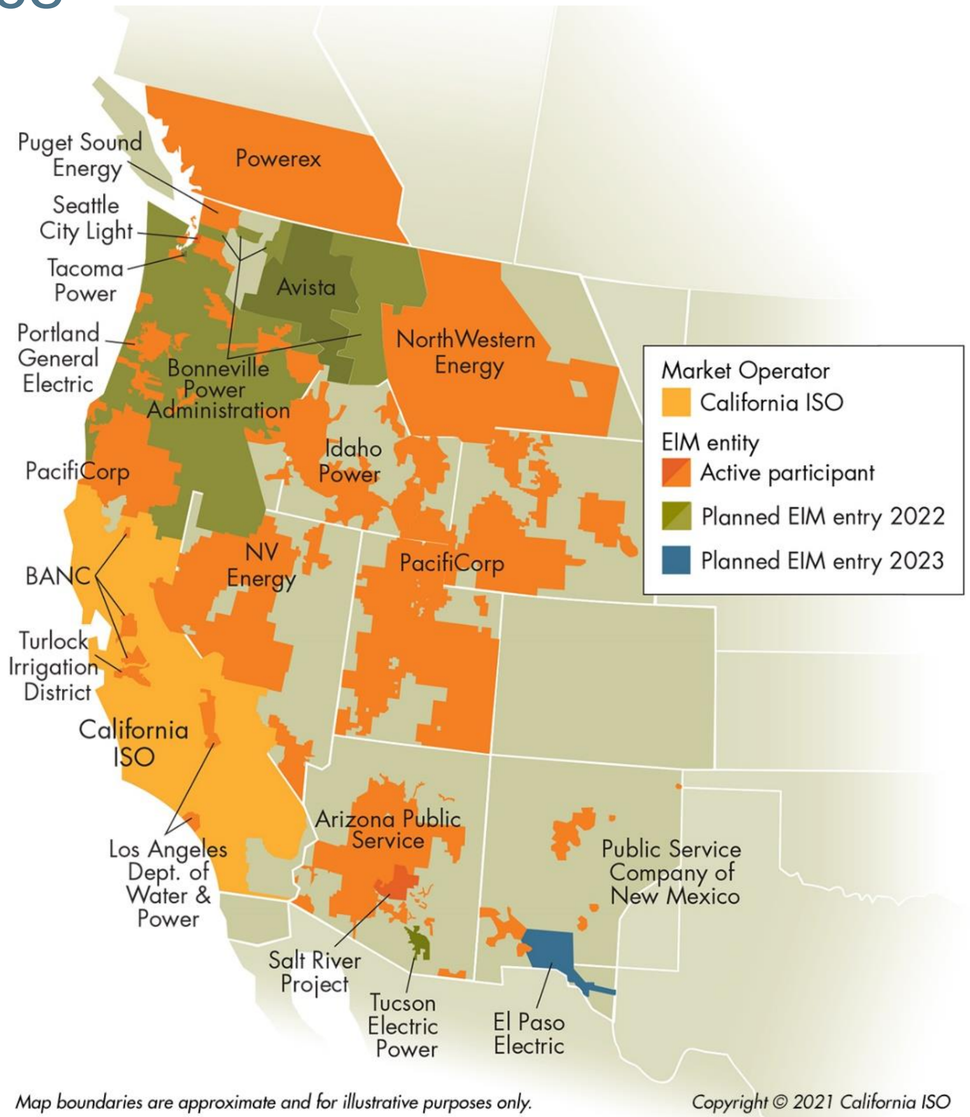


BA boundaries are approximate and for illustrative purposes only.

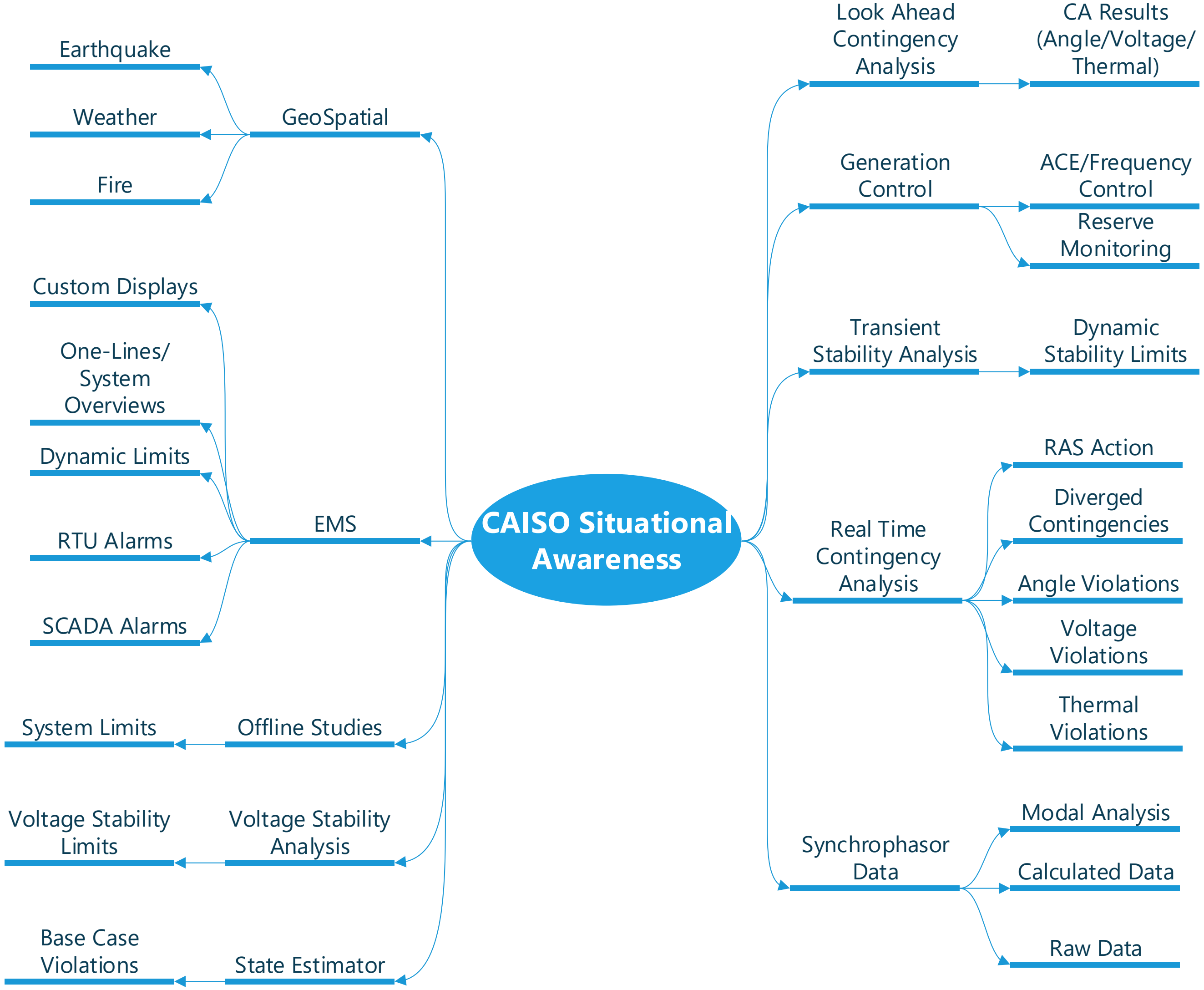
Western Energy Imbalance Market (EIM)

Since its launch in 2014, the Western EIM has enhanced grid reliability, generated millions of dollars in benefits for participants, and improved the integration of renewable energy resources.

- Gross benefits exceeding $1 billion
- Reduced over half a million metric tons of CO_2



Situational Awareness



Distributed Energy Resources Overview

- Physical Resources
  - Close to Load
  - Behind the meter
- Virtual Resources
- Types
  - Solar
  - Storage
  - Energy Efficiency
  - Demand Management

Impact of DERs on the Grid

- Avoided Infrastructure Investment
  - Avoided Generation by Central resources
  - Avoided losses on transmission system
  - Provide System capacity; Defer or avoid generation/transmission assets
- improved resilience
  - Flexibility
    - Frequency Regulation
    - Load Shaping
  - Operating reserves
- Increased integration of clean energy

Representing DERs in Grid Applications

- Modeling
  - Data Requirements
    - Telemetry required for all resources>10 MW
    - Provision of status every 4 sec
    - If providing AS; telemetry needed for participation; regardless of capacity

DER Models

- Proxy Demand Response (PDR) Model
  - Allows bidding demand response
  - Allows load curtailment independent of the Load Serving Entity
  - PDR-LSR (Load Shift Resource Model) allows bidirectional dispatch (increasing consumption during oversupply)
  - RDRR (Reliability Demand Response Resource); reliability based curtailment triggered under emergency

DER Models

- Distributed Energy Resource Provider (DERP)
  - Aggregation
  - Provides ability to meet minimum capacity requirements as one virtual aggregate resource
  - Minimum aggregate capacity of 0.5 MW

DER Models

- Non Generating Resource Model (NGR)
  - Resource Type Market Participation Model (such as a conventional generator)
  - Can support positive and negative range of a storage resource
  - In addition to DA/RT Spin and Non-Spin, can provide regulation as well

DER Models

- Non Generating Resource (NGR) Subtypes
  - Limited Energy Storage Resources
    - Support Continuous positive and negative operating range based on discharge and charge limits
    - Constrained by State of Charge
    - Batteries and Flywheels
  - Dispatchable Demand Response
    - Only a negative operating range
    - Cannot generate electricity
    - Constrained by curtailable energy limit
  - Generic NGRs
    - Continuous positive to negative operating range
    - Are not constrained by State of Charge

Market Handling of DERs

- Hourly and 15 minute DR Bidding Options
- Economic Day Ahead and Realtime
- Curtailment Services
  - Energy
  - AS Spinning
  - AS Non-Spin
  - Residual Unit Commitment
  - Bids in the ISO Markets as Supply
- Consumption Services
  - Energy

DER Market Characteristics

- Characteristics
  - Can bid in 10 kW increments
  - Minimum capacity 0.5 MW
  - Minimum load curtailment >= 100kW for energy
  - Minimum load curtailment >=500 kW for AS
  - Smaller loads may be aggregated to achieve minimum targets; max of 20 MW when spanning multiple p-nodes
  - Telemetry is required for resources >=10MW and/or AS certification

DER and System Operations

System operations tools for DER Monitoring:

- Special/Custom displays in EMS applications
- Custom built displays in PI
- Market application functionality around monitoring DER based energy and AS products
- Custom tools to dispatch Batteries/Storage to maintain the “State of Charge” requirements and system conditions

THANK YOU

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Future Session

- Session 3
  - Theme: Technique and Workforce Challenges
  - Time: 1:00 PM – 3:00 PM ET
  - Date: Thursday, 10/28/2021